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Interplay of Spin, Charge, and Structural Degrees of Freedom in Magnetoelectric $LuFe_2O_4$

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Recently, $LuFe_2O_4$ has been attracting attention as a potential multiferroic with the novel mechanism of ferroelectricity due to charge order and significant magnetoelectric coupling. Extraordinarily large magnetic coercivity also contributed to interest in this material. On a microscopic level, both magnetoelectric coupling and the large coercivity are connected to a complex interplay of spin, charge, and structural degrees of freedom. The elucidation of this interplay primarily through diffraction experiments will be presented. Combining macroscopic magnetization measurements with X-ray resonant magnetic scattering and neutron diffraction, a complex magnetic phase diagram, including partially disordered magnetic phases, is established. To relate the different magnetic phases with structural and charge-orbital degrees of freedom, supplementary measurements of nonresonant X-ray diffraction and resonant X-ray diffraction with polarization analysis were performed. One of the phase transitions involves spin and charge as well as structural degrees of freedom, the latter being the origin of the large coercivity and other unusual magnetic features. Other transitions involve primarily one degree of freedom, with only subtle coupling effects to the other degrees of freedom being observed. The relation of these effects to the observed magnetoelectric coupling will be discussed.